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Experimental Study of Alternatives to Sand in Zeer Pot Refrigeration Technique

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ABSTRACT: *Zeer Pot refrigeration technique is a simple evaporative cooling technique used for preservation of fruits and vegetables in hot and dry climate. In Zeer Pots sand is used as an insulating material which holds the water required for evaporative cooling. In this paper experimental analysis has been carried out by using Charcoal and Gunny cloth as alternatives and their performance has been compared to sand. The experiments have been conducted under three loading conditions – no load, respiratory load from 100gm and 500 gm of tomatoes. Results show that under all three loading conditions Gunny Cloth provides better results than charcoal and sand.*
Keywords: *Zeer Pot, Evaporative Cooling, Refrigeration, Sand, Charcoal, Gunny Cloth*

I. Introduction

With the degradation of ozone layer and harmful effects caused by the commercial refrigerants, importance is being given to utilization of renewable sources of energy and techniques that provide refrigeration without impairing the environment. Also, rural masses are at a disadvantage in procuring and maintaining a commercial refrigerator because of its high cost and continuous electric supply. Sometimes simple ancient techniques provide substantial knowledge and ideas towards innovatively building a new system in addressing the problems mentioned above. Zeer-Pot is one such system. It was invented in 1995 by Mohammed bah Abba of Nigeria primarily for rural farmers to preserve their produce. It was commercialized in 2000 as an inexpensive food storage system [1].

Zeer pot is a pot-in-pot arrangement of two clay pots made out of earthenware clay. The smaller diameter pot is placed inside the pot of larger diameter and the space between them is filled with sand. Water is poured to make the sand wet. The moist condition of sand between the pots is ensured. The fruits, vegetables and other products to be preserved are placed inside the smaller pot. The opening of the pot is covered with a moist cloth [1].

The voids present in the sand between the two pots holds the water poured. This water is evaporated to cool the space in the inner pot where food is kept. The evaporation is cause by convective and radiative heat transfer from the hot and dry climate of the surrounding and the cooling load from the food kept for preservation. The surrounding temperature and relative humidity along with the irreversible heat and mass transfer processes influences the temperature inside the inner pot. The irreversible heat and mass transfer is again influenced by the thermal conductivity of pot walls made of clay, sand and water in between the pots and surface area of inner and outer pots [2].

An experimental study of a system working on the principle of evaporative cooling suggests that jute, when used as absorbent material had better cooling efficiency compared to hessian cloth and cotton waste. But jute surfaces being prone to mold formation, cotton waste was considered the next best alternative [3]. This study suggests that usage of different materials having qualities of insulation and water absorption can be used as alternatives in evaporative coolers.

Charcoal coolers too are a type of evaporative coolers made out of timber frame. The frame is covered inside and outside with mesh leaving a cavity in-between. The cavity is then filled with pieces of charcoal. The charcoal is sprayed with water and once wet it assists in evaporative cooling [4].

In the literature above experimental analysis is not carried out by replacing sand in the Zeer pot. The purpose of this paper is to propose alternatives to sand for increasing the cooling efficiency of a Zeer pot. The alternatives should (i) be easily available for the rural masses and (ii) be inexpensive. A brief specification of the pot used in experiment is given in Section 2 followed by experimental set up details in Section 3. The results obtained are presented and discussed in Section 4 and finally the conclusion is reported in Section 5.

II. Specification of Zeer Pot

The Zeer Pot used in the present case is made out of natural earthen ware clay available easily and inexpensively to farmers. Clay is chosen because of its moldability, porosity and low thermal conductivity. The clay is mixed with water to increase its plasticity and also with sand particles of sizes less than 500µm to enhance passage of trapped air and water content when fired. The pots were prepared using wheel and then allowed to dry in shade for 7 days and then fired in a kiln. The pots were of spherical shape as shown in Fig.1 and their dimensions are: Outer pot height – 190mm, Outer pot surface area – $1.56x10^5$ mm^2, Outer pot thickness – 5mm. Inner pot height – 130 mm , Inner pot surface are – $0.73x10^5$ mm^2, Inner pot thickness – 5 mm.

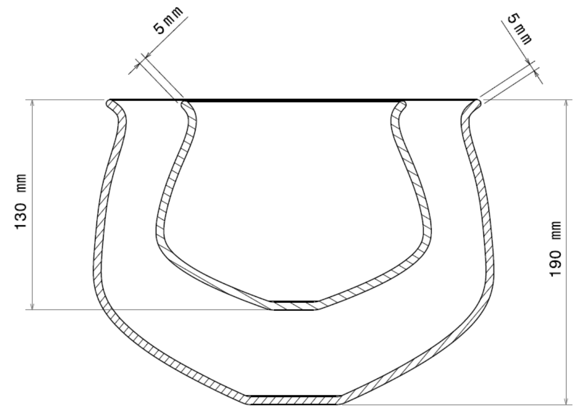

Figure 1: Specification of Zeer Pot used

Figure 2: Zeer Pot filled with (a) Sand (b) Charcoal (c) Gunny Cloth

Fig.2 shows the different cases of experimentation using sand, charcoal and gunny cloth. The sand used to fill the space in-between the pots were hand sieved to sizes 850µm and below. The gunny cloth was cut into small pieces to fill in the space and the pieces of charcoal used were of small sizes whose cross-sectional area being less than 400 mm^2.

III. Experimentation

The experimental set up is as shown in the Fig.3. The pots were placed in the shade to avoid direct radiation of sun. They were also placed at an elevation of 450mm from ground using a stand (not shown in Fig.3) to ensure flow of air completely around the pot to enhance available area for convection. The mouth is covered with a wet cloth. Experiments are carried out under natural convection. The same pots were used for experimentation with sand, jute and charcoal. First sand was added and water poured till sand was completely saturated with water.

A data logger is built using the ATmega328 microcontroller and temperature & humidity sensor AM2302/RHT03. The sensor's operational range of humidity is 0 to 100% RH and temperature is -40 to 80ºC. Accuracy is ± 2% Relative Humidity and temperature is less than ± 0.5ºC. Both the sensors were calibrated against each other before conducting the experiments. The sensing unit is a polymer capacitor for humidity and a thermistor for temperature. One sensor (HT1) was placed inside the inner pot and the other sensor (HT2) was placed 400mm away from the pot to sense the ambient air temperature and humidity. The sensors were connected to the microcontroller and the microcontroller was programmed to log data for every 3 seconds directly to the excel sheet on the remote computer. The readings were recorded from 08:00 to 21:30 hrs.

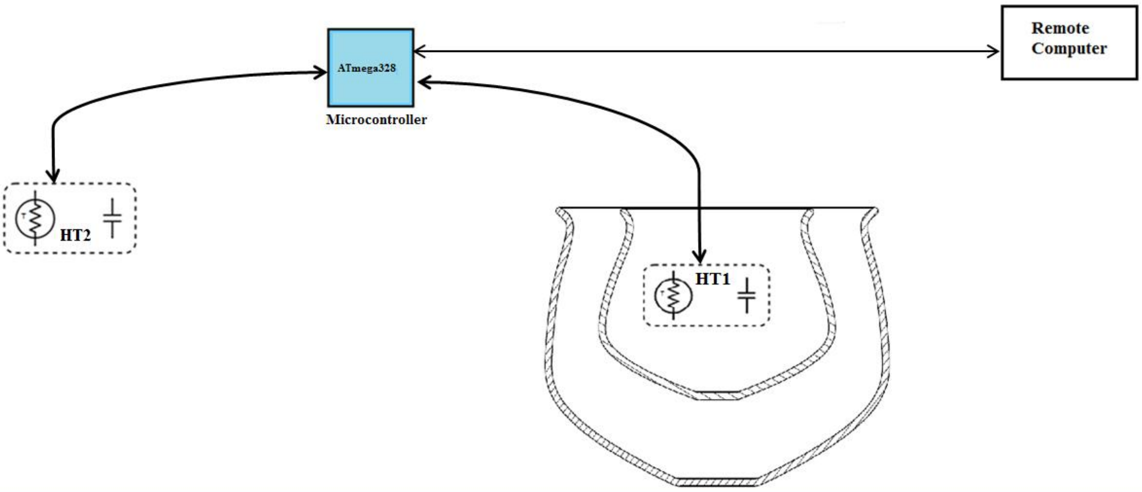

Figure 3: Experimental set up of Zeer pot

The experiment is repeated with charcoal and gunny cloth alternatively. The amount of material added by weight and water consumed by insulating material for saturation is detailed in Table 1. Using MATLAB, the readings are then plotted against time. Variation of inner temperature of inside pot, temperature difference achieved is compared when sand, gunny cloth and charcoal are used.

Experiments are also conducted by varying the respiratory cooling load. Tomatoes of 100gms and 500gms by weight are placed inside the inner pot alternatively. The variation of temperature is noted and plotted for all three materials one after the other.

Table 1 below shows amount of material added by weight in between the pots and the amount of water added to make the material completely saturated.

Table 1: Weight of material and measure of water added in experimentation

Material	Weight of the material in grams	Amount of water added in ml
Sand	5230	2000
Gunny Cloth	730	3100
Charcoal	920	2480

The wet bulb temperature was calculated using the formula [5]:

$$T_w = T*\text{atan}(0.151977*(RH+8.313659)^{1/2} + \text{atan}(T+RH) - \text{atan}(RH-1.676331) + 0.00391838*RH^{3/2}*\text{atan}(0.023101*RH) - 4.686035 \quad (1)$$

Where T_w = Wet Bulb Temperature in ºC; T = Air Temperature in ºC and RH = Relative Humidity of surrounding air in %. Difference between inner pot inside temperature and wet bulb temperature of surrounding air was plotted for all three conditions and compared.

IV. Results and Discussions

The results mainly consist of variation of inner pot inside temperature, ambient temperature and wet-bulb temperature with regards to time.

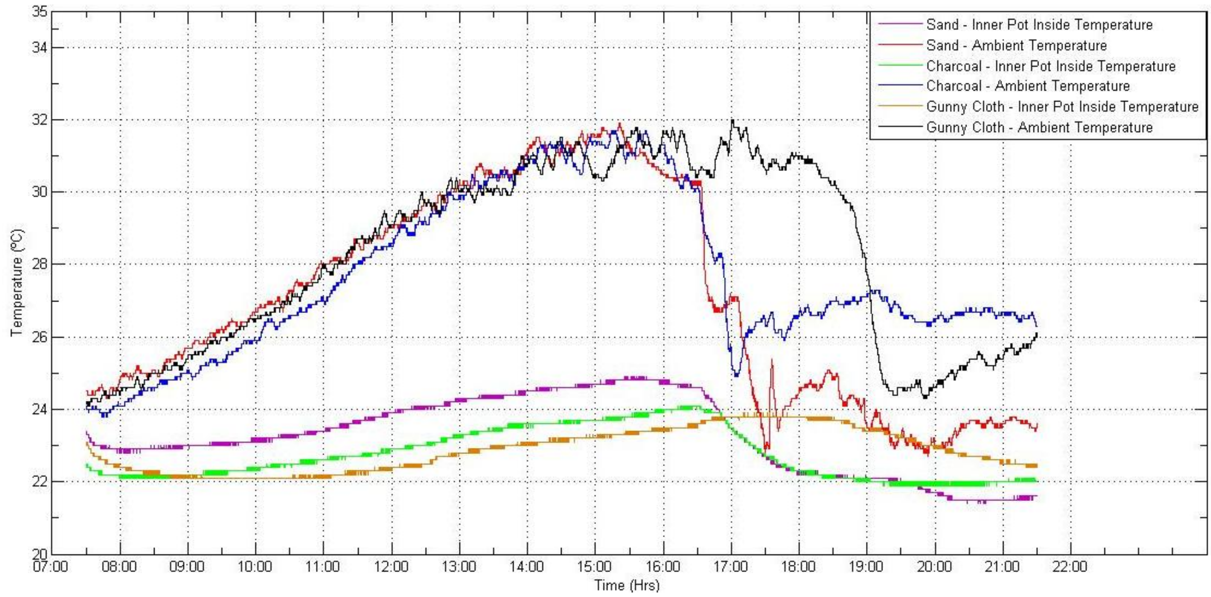

Figure 4: Variation of Inner Pot inside Temperature and Ambient Temperature for different materials

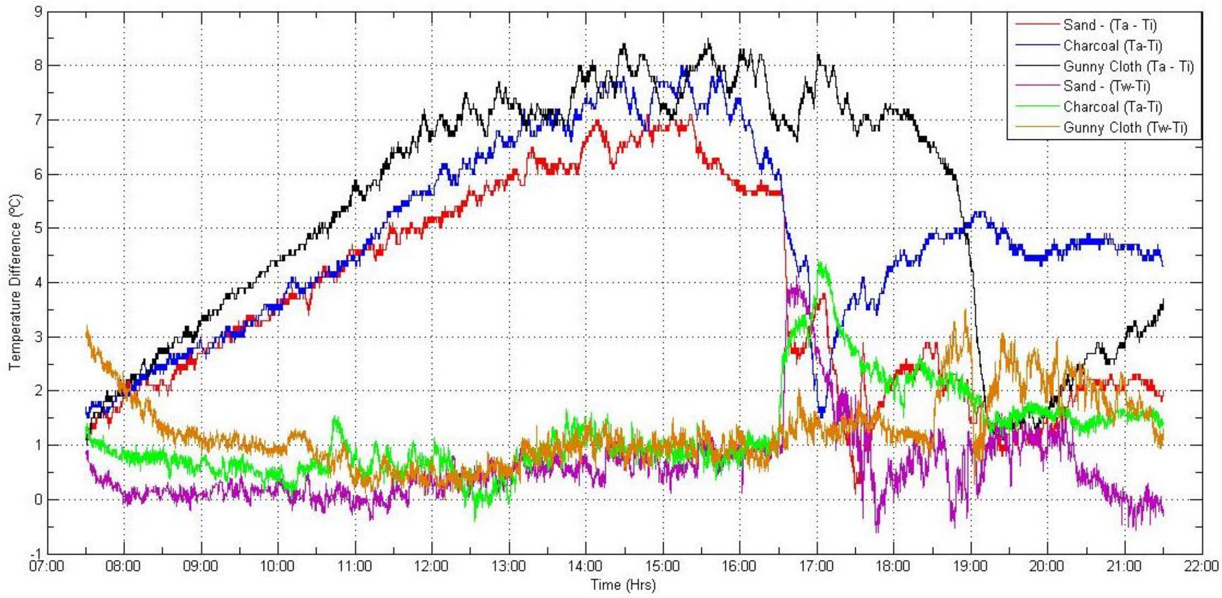

Figure 5: Difference between T_a & T_i and between T_w & T_i for different materials

Fig.4 shows variation of Inner pot inside temperature and ambient temperature with time for sand, charcoal and gunny cloth used as insulation and absorbent material in-between the pots. It is observed that Zeer pot arrangement when used with gunny cloth provides lower temperatures than used with sand or charcoal. It maintained its lower temperature in comparison, even when the ambient temperatures are at their maximum in noon from 15:00 to 16:00 Hrs. Fig.5 shows the temperature difference ($T_a - T_i$) achieved when used with sand, charcoal and gunny cloth. It can be seen that while sand managed to provided just around 7.0 ºC difference, charcoal managed a little better by providing 8.0 ºC and gunny cloth provided the maximum temperature difference of around 8.5 ºC. The difference between the wet-bulb temperature and the inner pot inside temperature ($T_w - T_i$) is observed from 09:00 Hrs and is found to be lower for sand. But it is in the range of 0.5 – 1.5 ºC for all three materials in the afternoon. When the ambient temperature decreased sharply due to rains, it was observed that the difference increases for all three materials before again stabilizing within the range.

Fig.6 shows variation of temperatures when 100gms of tomatoes were kept inside the inner pot. The readings were recorded from 08:15 to 21:30 Hrs.

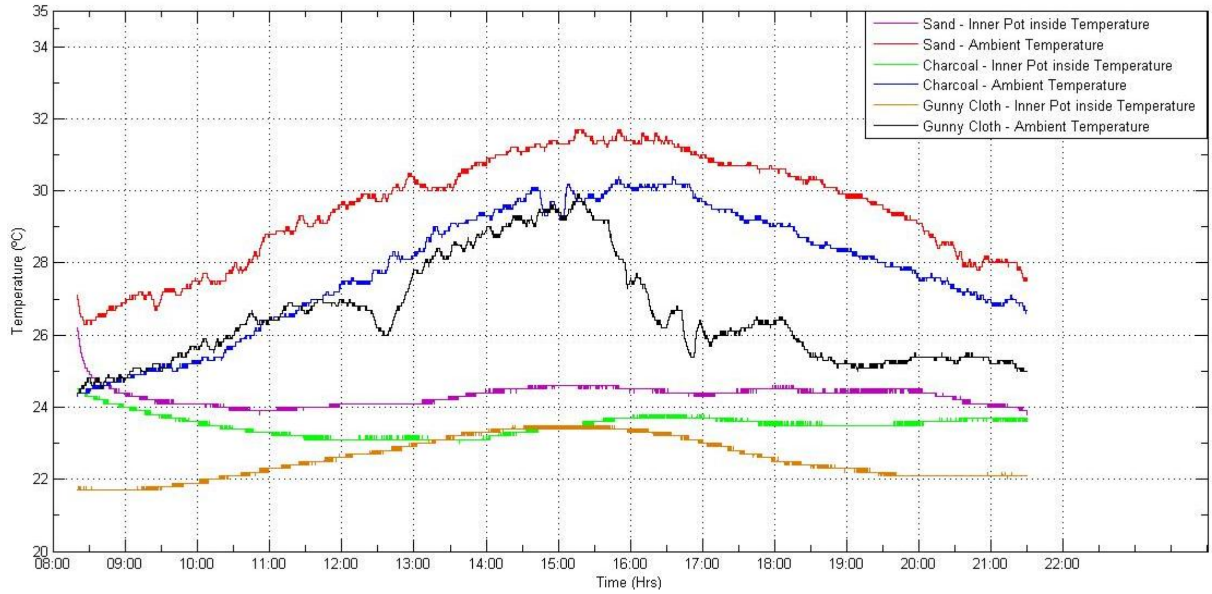

Figure 6: Variation of Inner Pot inside Temperature and Ambient Temperature with 100 gm tomatoes

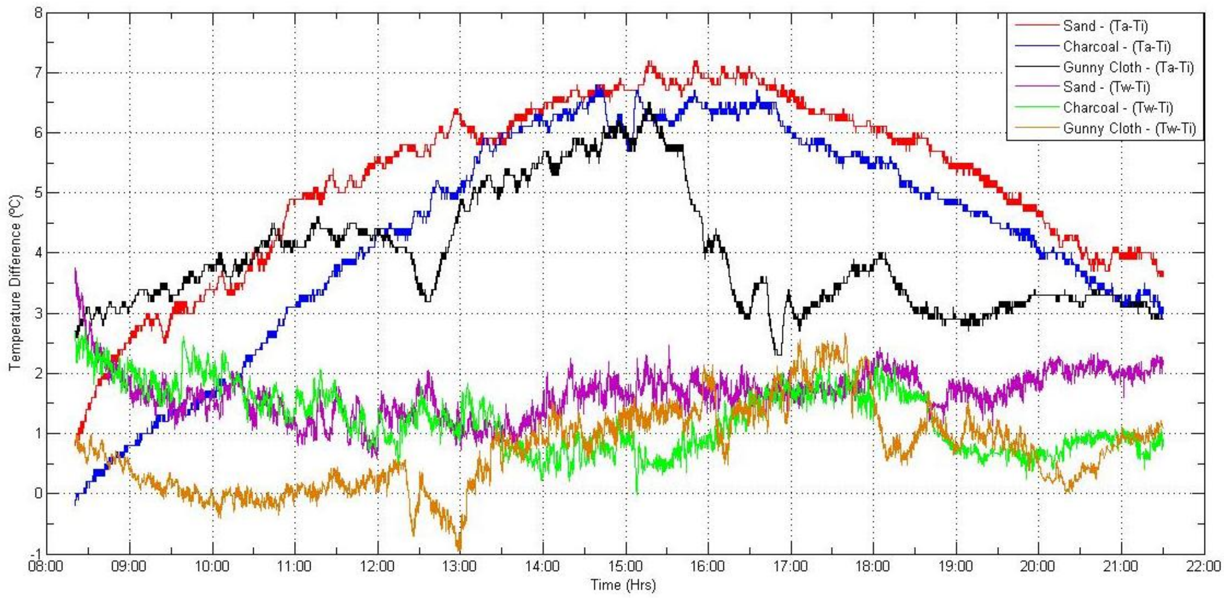

Figure 7: Difference between T_a & T_i and between T_w & T_i with 100 gm tomatoes

Fig.6 shows that the Zeer Pot with gunny cloth provides lower temperature than sand and charcoal. Again, charcoal fares better than sand in providing lower temperature for the preservation of food. Fig.7 shows that the temperature difference ($T_a – T_i$) provided by sand is greater than charcoal and gunny cloth. Even though gunny cloth provides temperature difference lesser than the other two materials, it is noticed that the ambient temperature prevalent during the experimentation of gunny cloth is lesser than the rest of the materials. When the ambient temperature itself is less, the amount of reduction in temperature required is also less for preservation of fruits and vegetables. This is because fruits and vegetables perish quickly at higher temperatures than at lower temperatures. Thus providing lower temperatures for food preservation is more important. It can also be seen that wet-bulb temperature difference ($T_w – T_i$) from 09:00 Hrs, provided by gunny cloth is lesser than charcoal and sand. It is observed that when gunny cloth is used the temperature inside the inner pot is almost equal to the wet bulb temperature of the ambient air for sufficient period of time. It even reaches to a temperature 1ºC less than the ambient surrounding temperature at around 13:00 hrs before fluctuating in the 0 – 1.5 ºC range. Charcoal also provides a difference in the same range for its entire period. Sand provides the difference in the range 0.5 – 2.0 ºC.

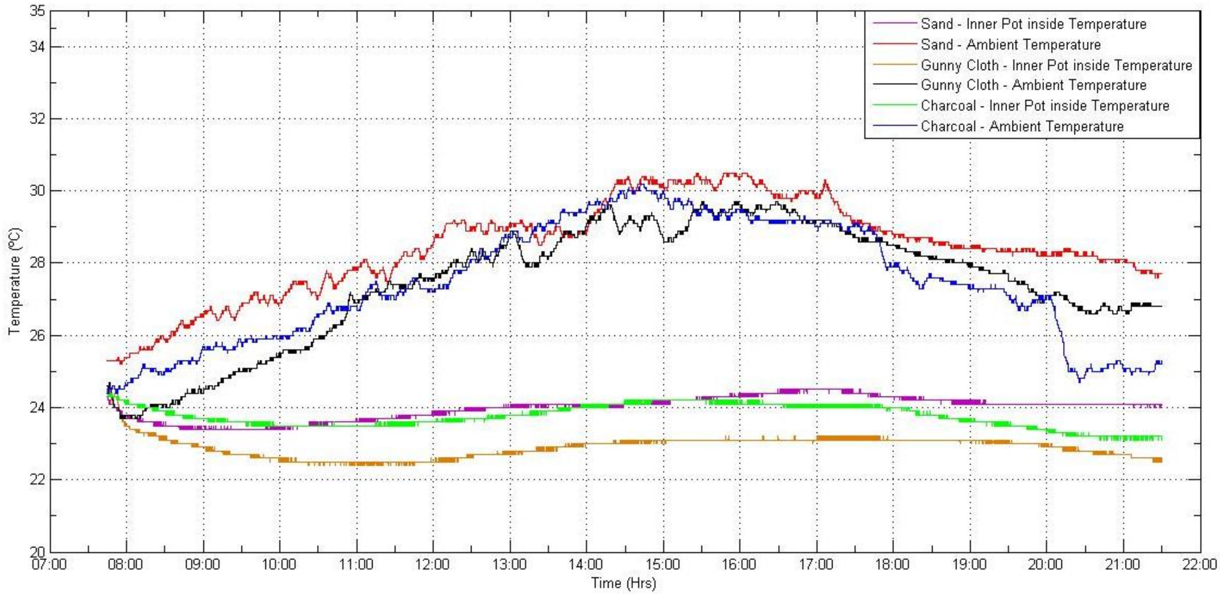

Figure 8: Variation of Inner Pot inside Temperature and Ambient Temperature with 500 gm Tomatoes

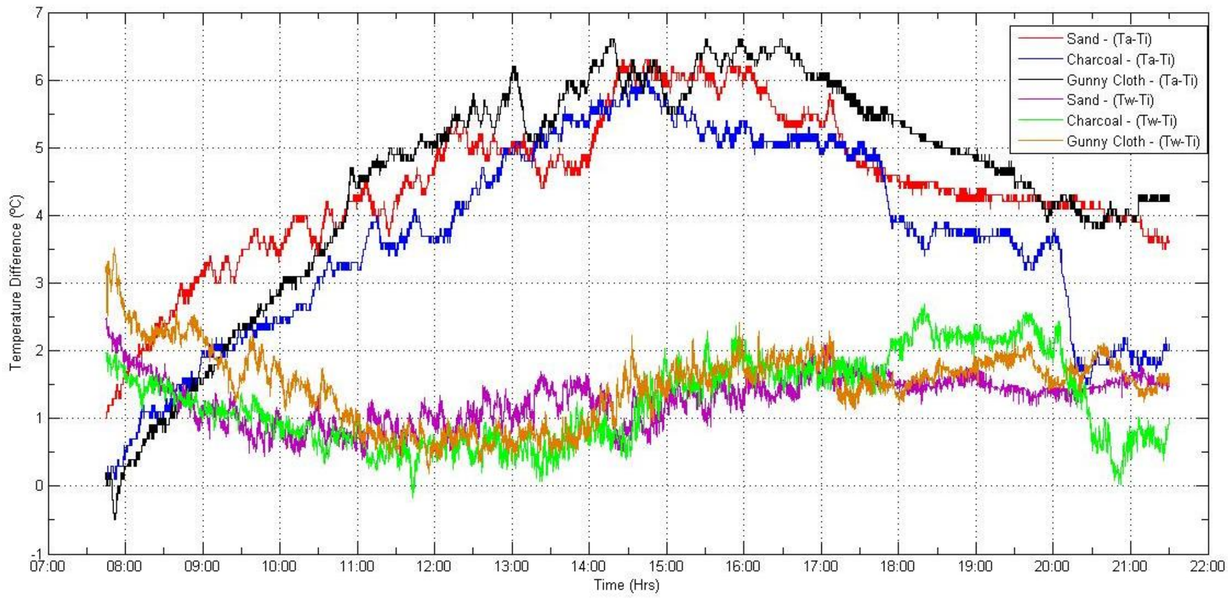

Figure 9: Difference between Ta & Ti and between Tw & Ti with 500 gm tomatoes

Fig. 8 and Fig. 9 shows the results obtained when 500 gm of tomatoes were kept instead of 100 gm to increase the cooling load. It is observed that again gunny cloth provides the lowest temperature compared to charcoal and sand. Lower temperatures achieved by charcoal and sand are almost equal till 16:00 hrs after which charcoal fares slightly better than sand. In terms of maximum temperature difference achieved, gunny cloth provides a difference of 6.5 ºC where as charcoal and sand provide just around 6.0 ºC. In terms of wet bulb temperature difference, all three fluctuate in the range 0 – 2.0 ºC from 10:00 to 18:00 Hrs.

All the above experimental results suggest that gunny cloth is better in providing lower temperatures. This is because the water absorbed by gunny cloth is more than charcoal and sand for the same volume existing between the two pots. Also gunny cloth is a better insulating material than charcoal and sand, thus keeping the variation of inner pot inside temperature minimum.

V. CONCLUSION

In this paper, experimental study has been carried out on the popular Zeer Pot technique of refrigeration by varying the material used between the pots. Experiments were also conducted varying the cooling load by adding 100gms and 500gms of tomatoes for all three materials. The materials – Sand, Charcoal and Gunny Cloth was alternatively experimented using the same pots and the main conclusions are:

1) All three materials provide significant temperature difference between T_i and Ta, which is essential for storage and preservation of agricultural produce. But gunny cloth is observed to provide the lowest temperature for all three cases of no load, respiratory cooling load of 100gm tomatoes and cooling load of 500gms tomatoes.
2) Charcoal provided the next best results in terms of gaining low temperature. It is observed that under no load and load of 100gms tomatoes, the lower temperature provided by charcoal is distinguishable from the sand but for a load 500gms of tomatoes both provide almost the same temperature.
3) The difference between T_w and T_i is found to be almost in the range 0 – 2.0 ºC for all three materials in all three cases of loading. Gunny cloth is observed to provide a temperature lesser than ambient wet bulb temperature for a brief period of time when a load of 100gms tomatoes is present.
4) Gunny Cloth and Charcoal are good alternatives to sand for preservation of fruits and vegetables by Zeer Pot technique. They both give better results than sand. They are also lighter in weight compared to sand and are easily available and inexpensive.

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